Cloud Based Acquisition System for Diabetic Data

Lucian Nita
Faculty of Electrical Engineering
"Gheorghe Asachi" Technical University of Iaşi,
RomSoft SRL
Iasi, Romania

Ferran Torrent-Fontbona
eXiT research group
University of Girona
Girona, Catalonia

***Abstract*—The paper presents a system which collects medical data from people with type 1 diabetes mellitus, stores the data into a cloud database and implements web pages for data analysis. This system architecture gives possibility to clinicians and patients to share information about patient evolution without the need for the patient to physically visit the hospital. The system includes a clinical decision support system which helps the patient on insulin doses calibration.**

***Keywords*—cloud database, web services, diabetics data, clinical decision suport system**

I. Introduction

There are many cases when data acquisitioned by a system has to be shared between several actors working in different geographic areas. One example is given by data acquisition systems for diabetic people which have to send the information to a clinician in order to advise the patient about his treatment.

Diabetes is not a so severe disease that requires patient hospitalization, but on the other hand, the patient cannot be left alone in the decision of the day by day treatment. Deciding the insulin dose that the patient has to intake is a continuous struggle in which the patient needs the doctor's support. In this case, a cloud database is needed where both, patient and clinician, have access and can share information about patient like blood glucose value (BGV), meals, physical activity, etc., and the insulin dose needed in order to maintain the BGV in a safety range.

II. System Architecture

The system architecture (Fig.1) includes a data acquisition block which collects the patient data, a cloud database where the entire information is stored, a web services block which makes the database visible on the internet, and a user interface block which enables users to interact with the system.

The system is not designed for only gathering data, since it also integrates a Clinical Decision Support System (CDSS) which helps users to take the correct decision about insulin dose in a given context. The CDSS is a Case Based Reasoning (CBR) [1] algorithm which analyzes the patient context and recommends an insulin dose using information from past user's experiences.

The user interface is built as a web application. Therefore, it is available anytime, anywhere. This is a great advantage of the cloud based acquisition systems, since the user can access data using a mobile phone, a tablet, or a computer connected to the internet.

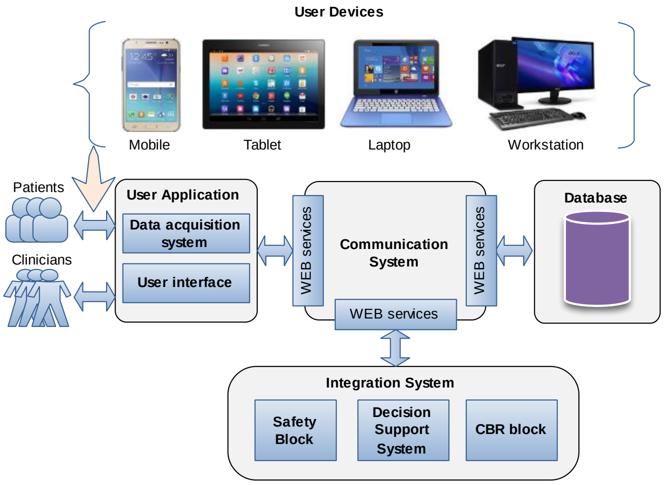

Figure 1. System architecture

One big problem for medical applications to be accepted by the end users is given by their accessibility. Even if an application is very useful for a patient, including a powerful computational algorithm, which helps the user taking the right decisions, if the application is not user friendly, then it will be not accepted by the end user. Thus, the system has been designed to be available on all devices and to be easy to use by a common person, who does not have specific skills on informatics.

III. The Database

The database (DB) is the unique place where all information used by system is stored. Having a unique database for all users and with all the information eases the task of building complex data reports, data analyses and data validation rules.

Due to the large amount of data gatehred from patients, the system has to use a professional database. In this context, the system uses a Microsoft SQL Server [2] database which includes all functionalities needed for such purpose (triggers, stored procedures, multiple connections on the same time, large amount of data, etc).

In addition, this database is integrated with the Microsoft ADO.NET Entity Framework [3] which automates the development of database tables making the development work more productive and less liable to errors.

The database implements tables for each data object sent by patient acquisition block:

- Patient table: stores all the information about the patient (weight, age, HbA1c, patient medical history, etc).
- BGValue: stores the list a blood glucose values measured by Continuous Glucose Monitoring (CGM) devices [4], or other portable blood glucose meters.
- Meal: all carbohydrates intakes have to be stored into database because the meals represent a key parameter for the CDSS algorithm.
- Physical Activity: is another factor which decides the insulin dose for the patient.
- Insulin Injection: stores the insulin amount taken by the patient during each day. There are two types of insulin: basal, which is a slow insulin which can control the blood sugar for an entire day, and bolus insulin, which is a fast insulin and is usually taken before each meal in order to compensate the carbohydrates intake.

IV. THE COMMUNICATION SYSTEM (CS)

This component implements the cloud concept for the acquisition system. The CS is composed by a series of web services, which run 24 hours per day, seven days per week. For each type of data transmitted into the system, the CS will build a specific REST (Representational State Transfer) web service [5] implementing all four HTTP verbs (Post, Get, Put, Delete) corresponding to the four CRUD operations into database (Create, Read, Update, Delete):

TABLE I. HTTP VERBS IMPLEMENTED BY COMMUNICATION SYSTEM

HTTP verb	CRUD	Response
POST	Create	201 - Created 404 - Not Found 409 - Conflicts
GET	Read	200 - OK 404 - Not Found
PUT	Update/Replace	200 - OK 404 - Not Found 204 - No Content
DELETE	Delete	200 - OK 404 - Not Found

REST is a web standard which uses HTTP Protocol for data communication. In a REST architecture, the server provides access to the requested resources identified by a specific Uniform Resource Identifier (URI) and the REST client presents this resource. Software applications written in various programming languages and run on various platforms can use this open standard in order to exchange data. Then, the Communication Block integrates into a single functional system all software modules developed by different providers on different languages.

V. USER INTERFACE

The user interface is implemented by a web application, which builds customized pages for each user type (patient, clinician, administrator).

One specific challenge of the system is given by the patient data privacy. The patient is the owner of the medical data stored into the cloud database and only the patient can give permissions to other actors to access his personal data. In this context, the application implements a system of roles, each role having specific rights on data accessing. Each user is assigned to a given role, so the user is granted with the corresponding rights: patients can access only to their own data, clinicians can access to the data of those patients that had given their agreement. Without an account and password, nobody can access the system data.

The main page of application displays the patients list registered into the system and includes link buttons, which redirect the user to other pages displaying more information for a selected patient:

- View/edit patient profile: displays and edits the patient demographic data.
- Patient data displays the medical data received for the selected patient.
- Notes, Alarms: displays the messages sent by the patient and the alarms raised by the data acquisition block (sensors disconnected, hyper/hypoglycemia, etc.).
- The application is Multilanguage, each text could be displayed in one of the three implemented languages (English, Spanish and Catalan). When the user selects a language, that setting is stored into a browser cookie and used until the next setting.

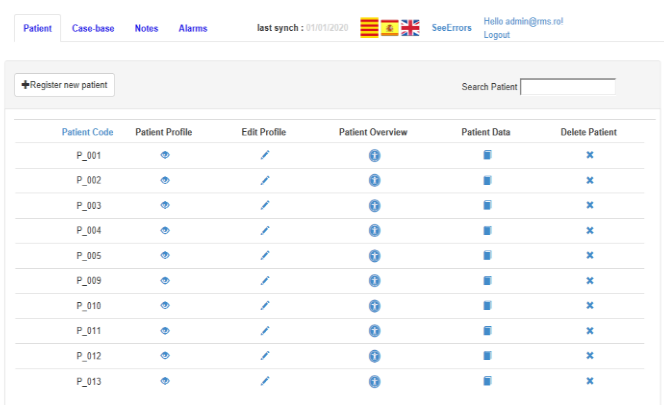

Figure 2: Application main page

The patient register page (Fig.3) allows to store the meaningful information about the new patient: gender, weight, low and high glucose thresholds, HbA1c (a value which gives an overall picture about blood glucose level during the last month), therapy type, etc.

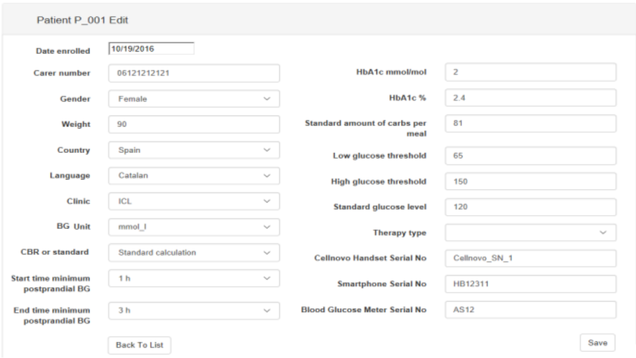

Figure 3: Patient register page

VI. DATA ANALYSIS

Data analysis is a very important functionality of the system. The main advantage of the cloud based system is given by the fact that different actors can access the same data, analyze and share conclusions regarding the patient evolution. But for giving correct advices, the clinicians need a powerful data analysis tool.

In this context, the system develops some meaningful graphs which display complex reports about patient's data and point out some trends on patient evolution.

One of these pages is given by CGM data analysis (Fig.4). The graph reads from database the CGM values for a given interval (week, month, specific days (Mondays, Sundays, etc.) and builds a generic day of 24 hours with those values. All CGM values having the same minute (for example 10:30 AM) from the selected interval, are stored into a vector having as many points as the number of selected days. From this vector, the system calculates some statistic values (mean, max, median, interquartile range) which reflects the real CGM trends for that minute.

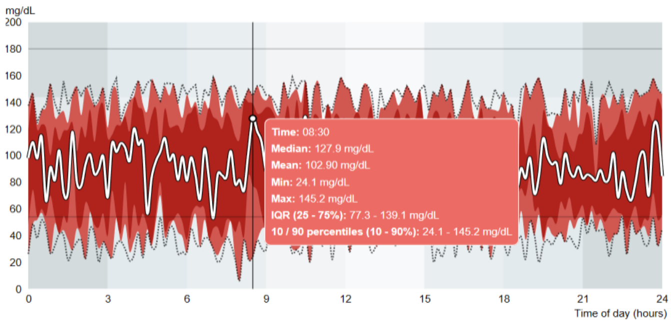

Figure 4: CGM trends for a generic day

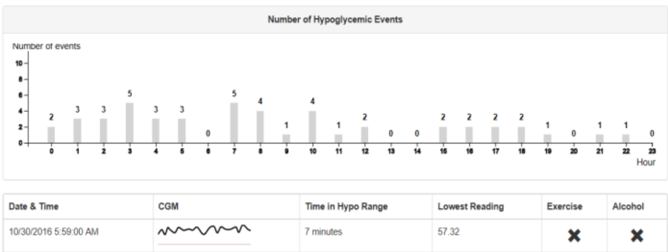

Figure 5: Hypoglycemic events for a generic day

Another useful graph displays the number of hypo/hyperglycemia events for the same generic day (Fig.5). The figure displays how many events occur for each hour in the selected interval and also the context for each event: (the CGM curve around the time event, how much time the event lasts, exercise or alcohol events).

VII. DECISION SUPPORT SYSTEM

In fact, the main advantage of this acquisition system is given by the CDSS. There are many applications on the market that gather data for people with diabetes and display the trends, but very few can advise the patient about the insulin dose for a given context. However, applications recommending bolus doses are usually simple bolus calculators which are too general and ineffective or demand too specific information to the user.

The presented system incorporates a bolus recommender system based on CBR [6]. CBR is a lazy learning methodology, which consists of using past experiences to solve future problems. It basically consists of four main steps: (i) identifying prior experiences similar to the problem to be solved; (ii) adapt the solutions of prior experiences to find a solution to the new problem; (iii) evaluate the outcome of the proposed solution and repair it if necessary; and (iv) store the current experience (problem and solution) for further problems and manage the stored experiences.

The proposed recommender system has the objective of recommending personalized and adaptive bolus doses to people with type 1 diabetes without asking for complex, and usually unknown, parameters to the user such as the insulin to carbohydrates ratio (ICR) or the insulin sensitivity factor (ISF) used by any bolus calculator.

Instead, the presented system considers other information (e.g. past and future physical activity, time of the day, type of day, stress, hours of sleep, hormone cycle, etc.) to select past experiences similar to the current situation. Moreover, the system does not require accurate information but consistent. In fact, this information is required with only two, three or four quantification levels (e.g. yes/no or none/low/mild/high).

Then, it uses past solutions to derive an appropriate new solution according to the similarity between experiences. Solutions are not bolus doses but the ICR of the patient. Then, the ICR is used to calculate the bolus dose as follows:

$$B = \frac{CHO}{ICR} + \frac{G_c - G_{sp}}{ISF} - IOB$$

Where CHO is the carbohydrates intake, G_c is the current blood glucose value, G_{sp} is the glucose reference value, IOB is the remaining active insulin from past doses calculated as stated in [7], and ISF is the insulin sensitivity factor of the user calculated as stated in [8] using the following equation:

$$ISF = \frac{341.94 \cdot ICR}{W}$$

Where W is the user body weight. Therefore, the proposed system estimates user diabetes-related parameters (ICR and ISF) using context information, instead of asking the user for them. Then it calculates the appropriate bolus dose for a particular carbohydrates intake, glucose level and active insulin as any traditional bolus calculator.

After that, the system keeps gathering glucose values using the CGM. Glucose values are then used to revise the outcome of the recommended bolus dose. If postprandial glucose values involve hypoglycemia or hypoglycemia, then the proposed ICR corrected as proposed in [6]. In particular, it estimates which bolus should have been administered in order to avoid hypo- or hyperglycemia using the previously estimated ISF. Then, it updates the ICR so the calculated bolus dose matches with the corrected one. This correction step permits the system and iterative improvement of the solutions to optimize them or to follow any user's evolution.

Finally, the system evaluates which are the most relevant past experiences in order to only save them and increase system's efficiency.

Therefore, the system is capable to recommend bolus doses only using rough information about common features for people with type 1 diabetes like physical activity, carbohydrates intake, etc., and information about blood glucose from a CGM.

VIII. CONCLUSIONS

A system which gathers and stores into a cloud database the diabetics medical data is presented. The system is not only for data gathering but also implements powerful functionalities for data analysis and decision support. The proposed architecture ensures several important advantages for the system:

- Accessibility: the system is cloud based, can be accessed anytime, anywhere. All smart devices having an internet connection (mobile phones, tablets, laptops) can be used for accessing the system.
- Data sharing: different actors (patients, clinicians) can share medical data and advices about treatment without needing to physically meet each other.
- Data analyzing: the system uses the latest technologies on internet field (JQuery, Data Driven Documents, SVG, CSS) which make possible to build interactive and powerful graphs on web pages.
- Decision Support System: implements machine learning algorithms which provide personalized and adaptive advices regarding the treatment of diabetes.

ACKNOWLEDGMENT

This material is based upon the work which is supported by the European Union through the H2020 "PEPPER" project: Patient Empowerment through Predictive Personalized decision support, http://www.pepper.eu.com .

REFERENCES

[1] Aamodt, A., Plaza, E. Case-based reasoning: Foundational issues, methodological variations, and system apporaches. *AI communications* 7(1), 39-59 (1994)

[2] Microsoft SQL Server 2016, https://www.microsoft.com/en-us/sql-server/sql-server-2016

[3] Microsoft ADO.NET Entity Framework, http://www.entityframeworktutorial.net/what-is-entityframework.aspx

[4] Continuous glucose monitoring (CGM), https://www.dexcom.com/continuous-glucose-monitoring

[5] RESTful Web Services, https://www.tutorialspoint.com/restful/restful_introduction.htm

[6] Torrent-Fontbona, F., Lopez, B., Pozo-Alonso, A. A CBR-based bolus recommender system for type 1 diabetes. *AIME 2017 Workshop on Artificial Intelligence for Diabetes (AID 2017)*, Vienna, 2017

[7] Brown, D. Temporal case-based reasoning for insulin decision support. Ph.D. thesis, Oxford Brookes University (2015).

[8] Walsh, Y., Gao, F., Doyle, F.J. Guidelines for optimal bolus calculator settings in adults. *Journal of Diabetes Science and Technology* 5(1), 129-135 (2011)